Uncertainties in the trends of black carbon emissions: Contribution to vertical temperature change

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Outline

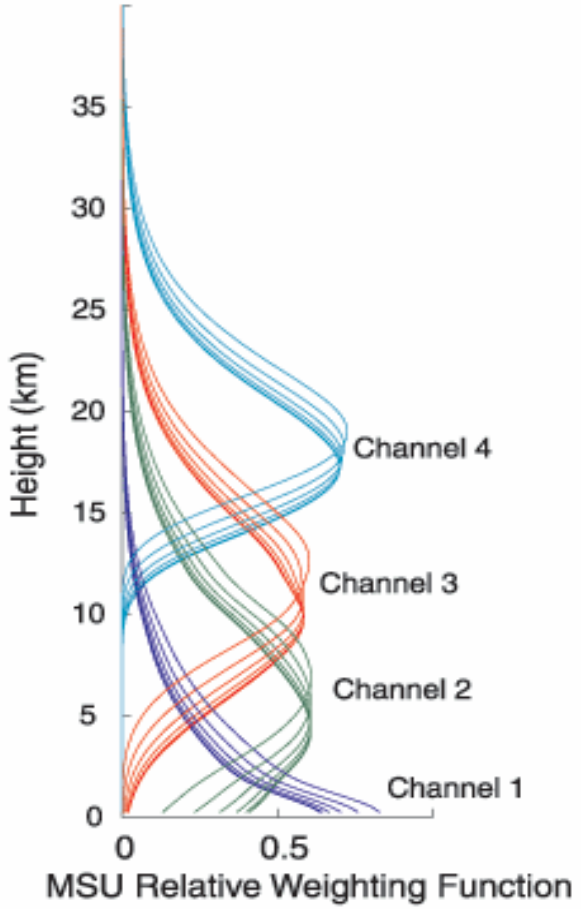
- Measured trends at surface and mid-troposphere
- Temperature trend in numerical simulations.
- BC’s role in temperature trend.
- Issues for the future

Surface temperature trend

Group	1890-1998(K/decade)	1979-1998(K/decade)
Jones et al (1999)	0.059	0.19
Quayle et al (1999)	0.053	0.17
Hansen et al (1999)	0.053	0.13

Source: Reconciling observations of global temperature change, National Research Council, 2001.

Troposphere temperature



- Radiometers on satellite

- The temperature sounding microwave radiometer (MSU) on NOAA's polar orbiting weather satellites, started in 1979;
- MSU measures temperatures in broad atmospheric layers according to the weighting function from different channels.
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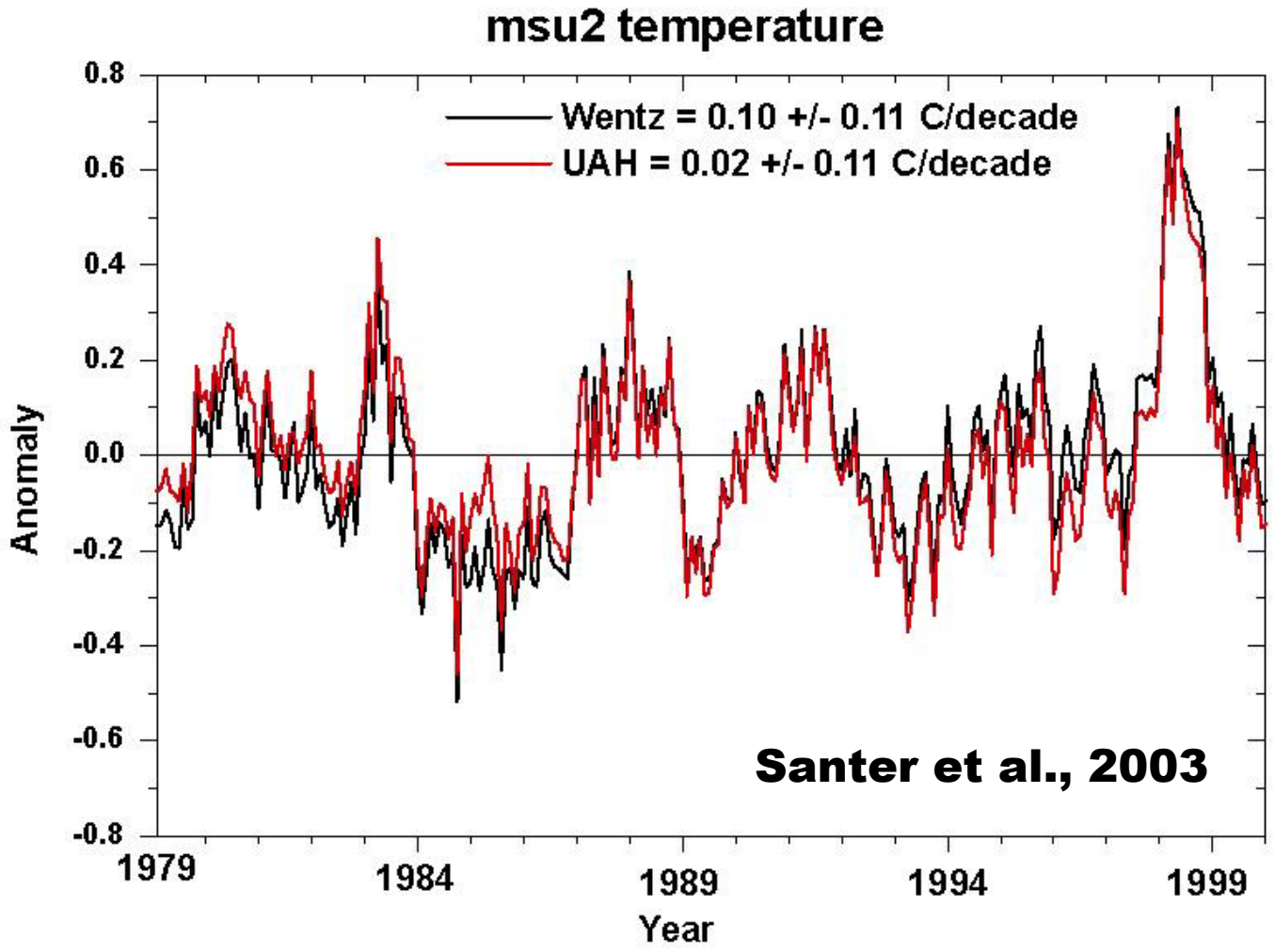
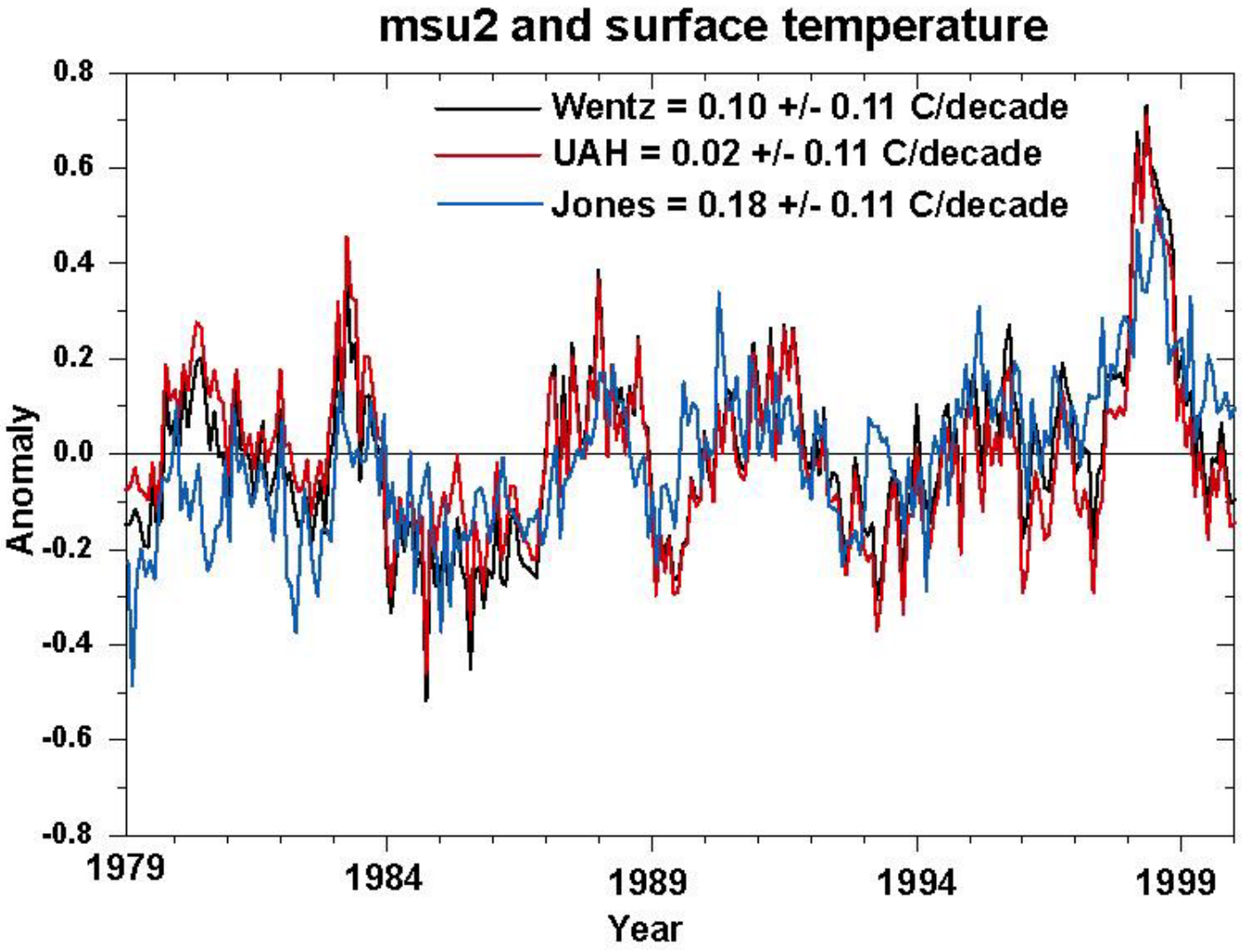
- Provides comprehensive global coverage, and consecutive temporal coverage

MSU temperature trends by different groups:

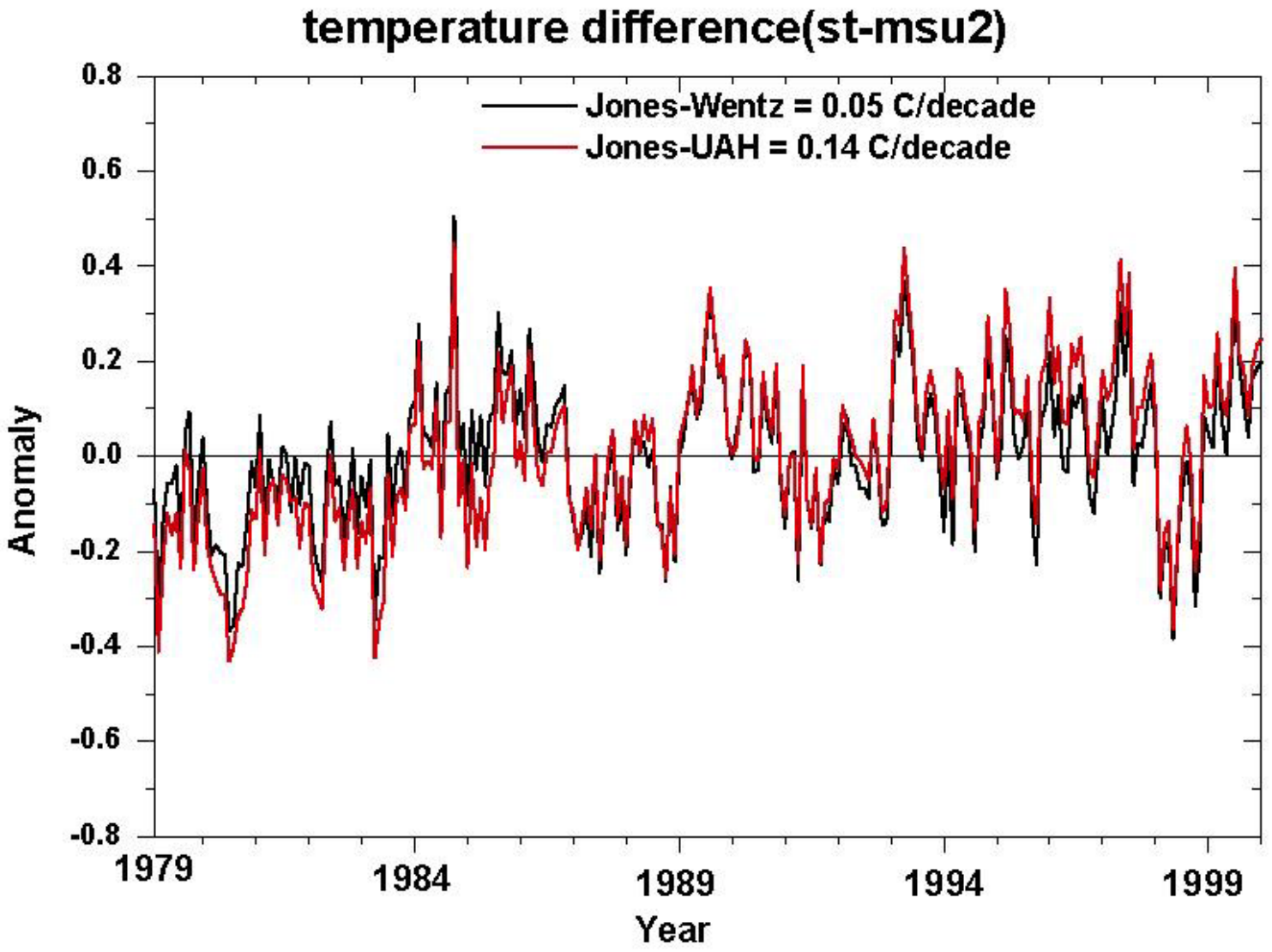


Vinnikov and Grody: 0.22 to 0.26 C/decade (79-02)

Comparison of MSU trend and surface trend



Observed difference: surface – MSU



1958 - 1997 Temperature Trends: Radiosonde network

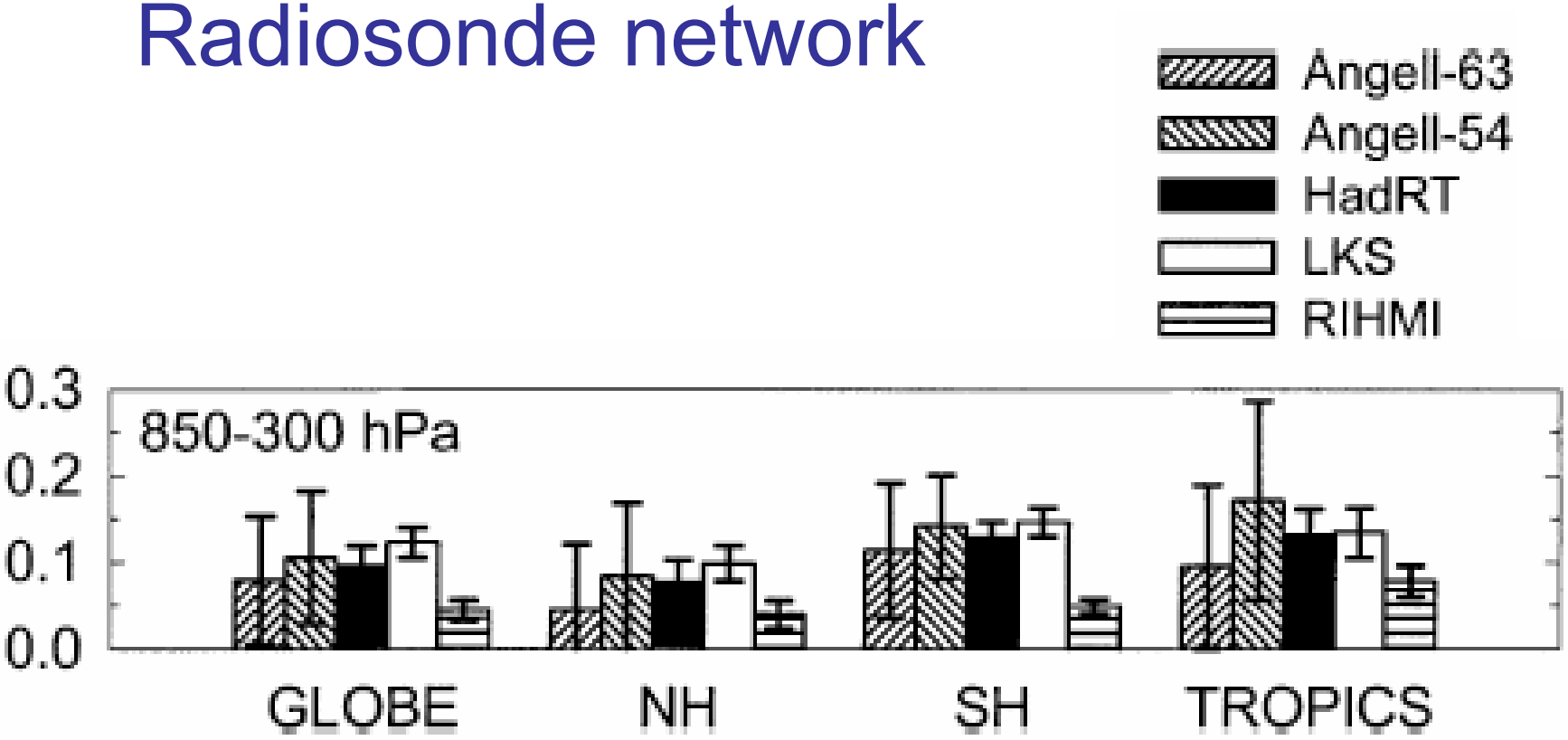
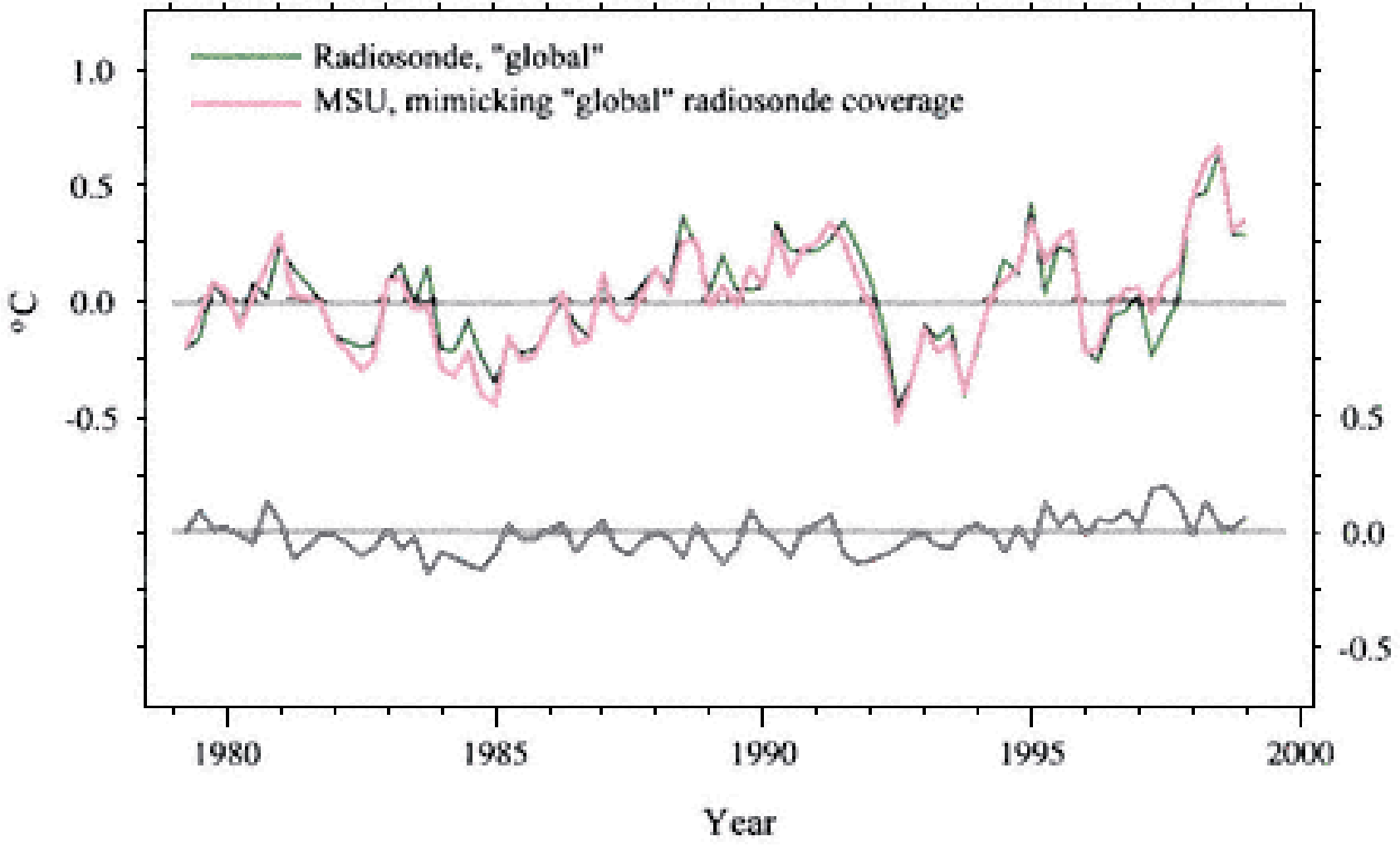
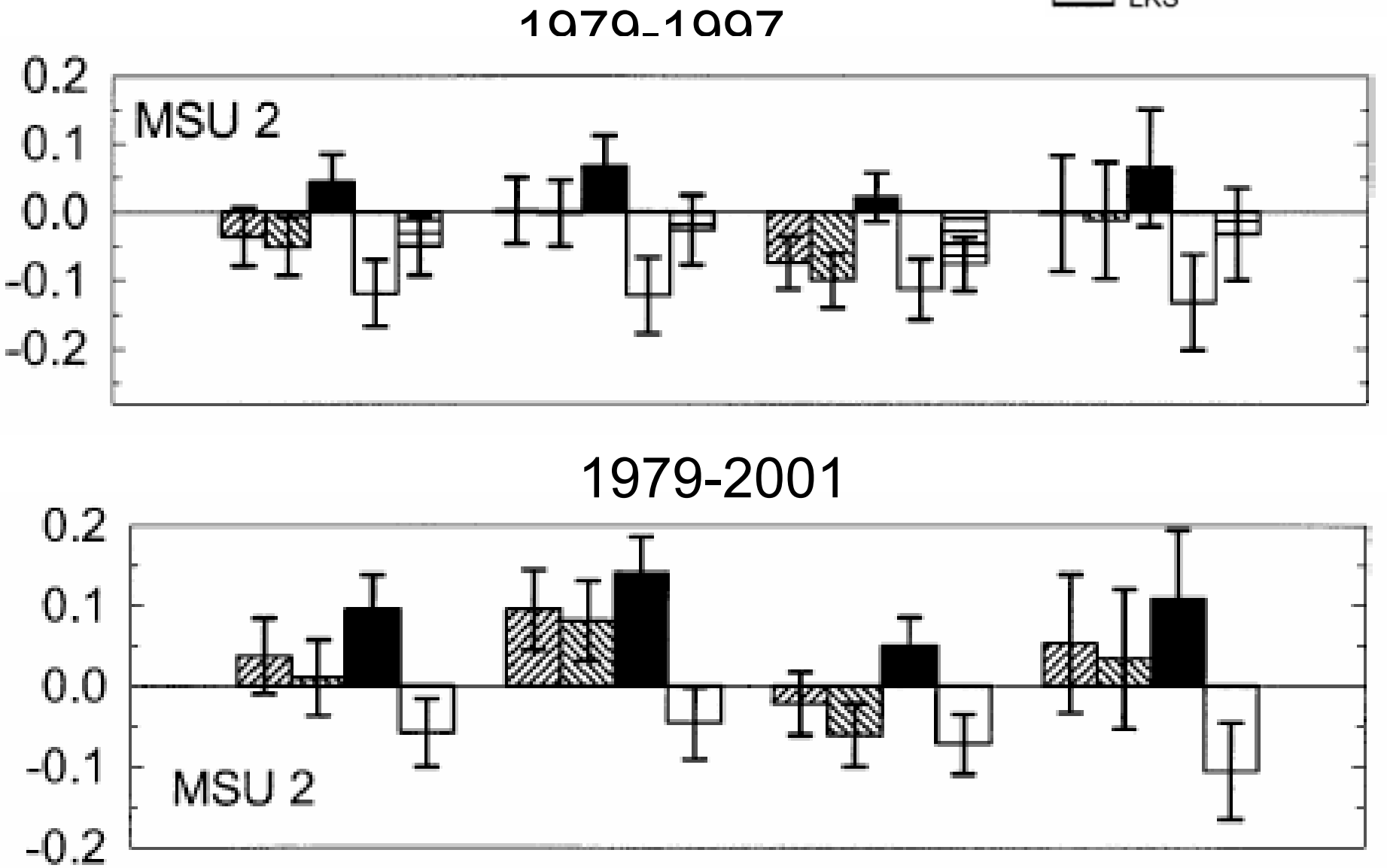


FIG. 12. Trends (K decade^{-1}) in global temperature for 1958–97 for three layers (top) 100–50, (middle) 300–100, (bottom) 850–300 hPa, in four regions, from radiosonde datasets. The confidence intervals shown are the ± 1 standard error uncertainty estimates.

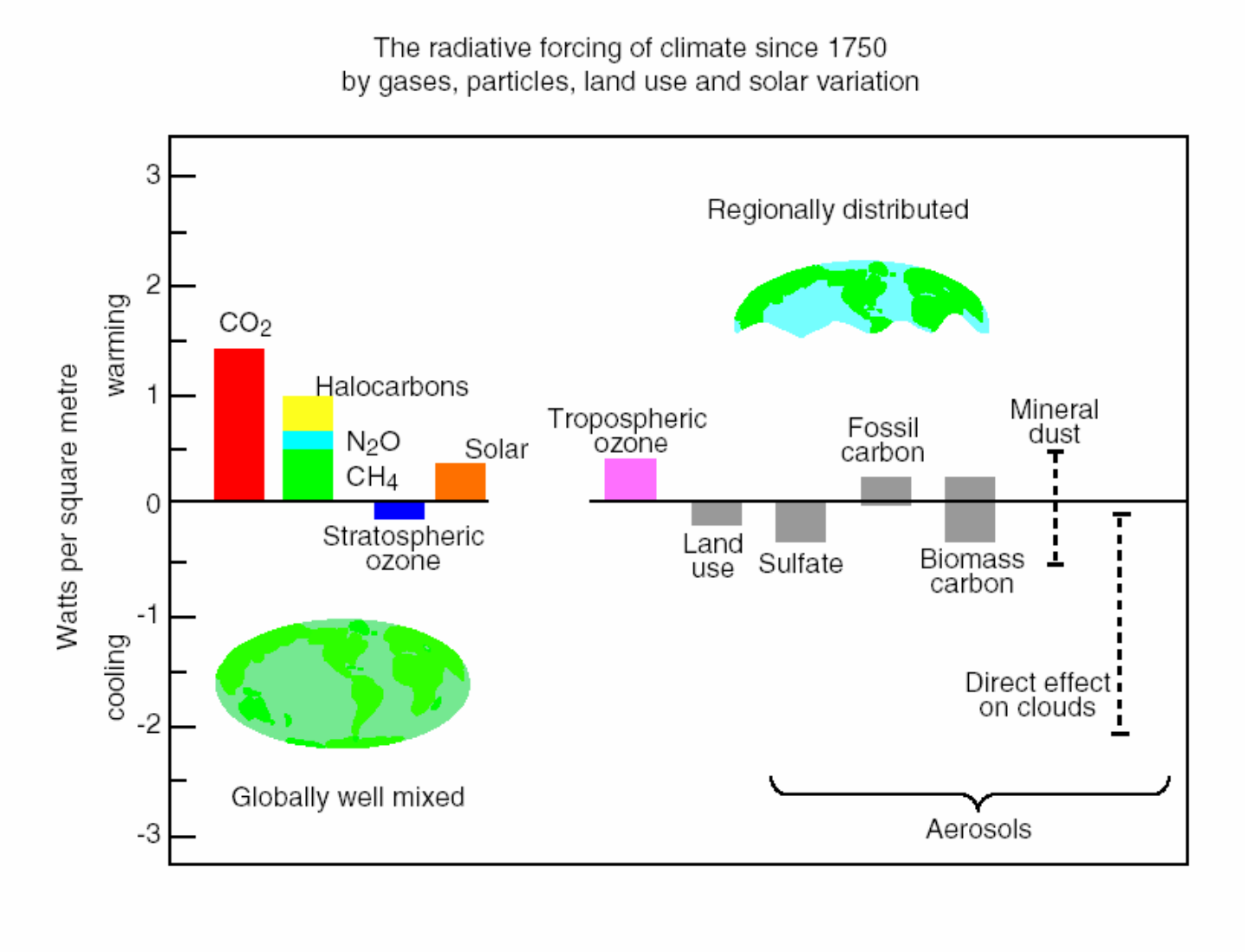
Comparison of UAH trends and radiosonde trends



Comparison of radiosonde and MSU2 trends-Seidel et al. 2004



What do we expect from climate model simulations?



Model calculated temperature change from external forcing

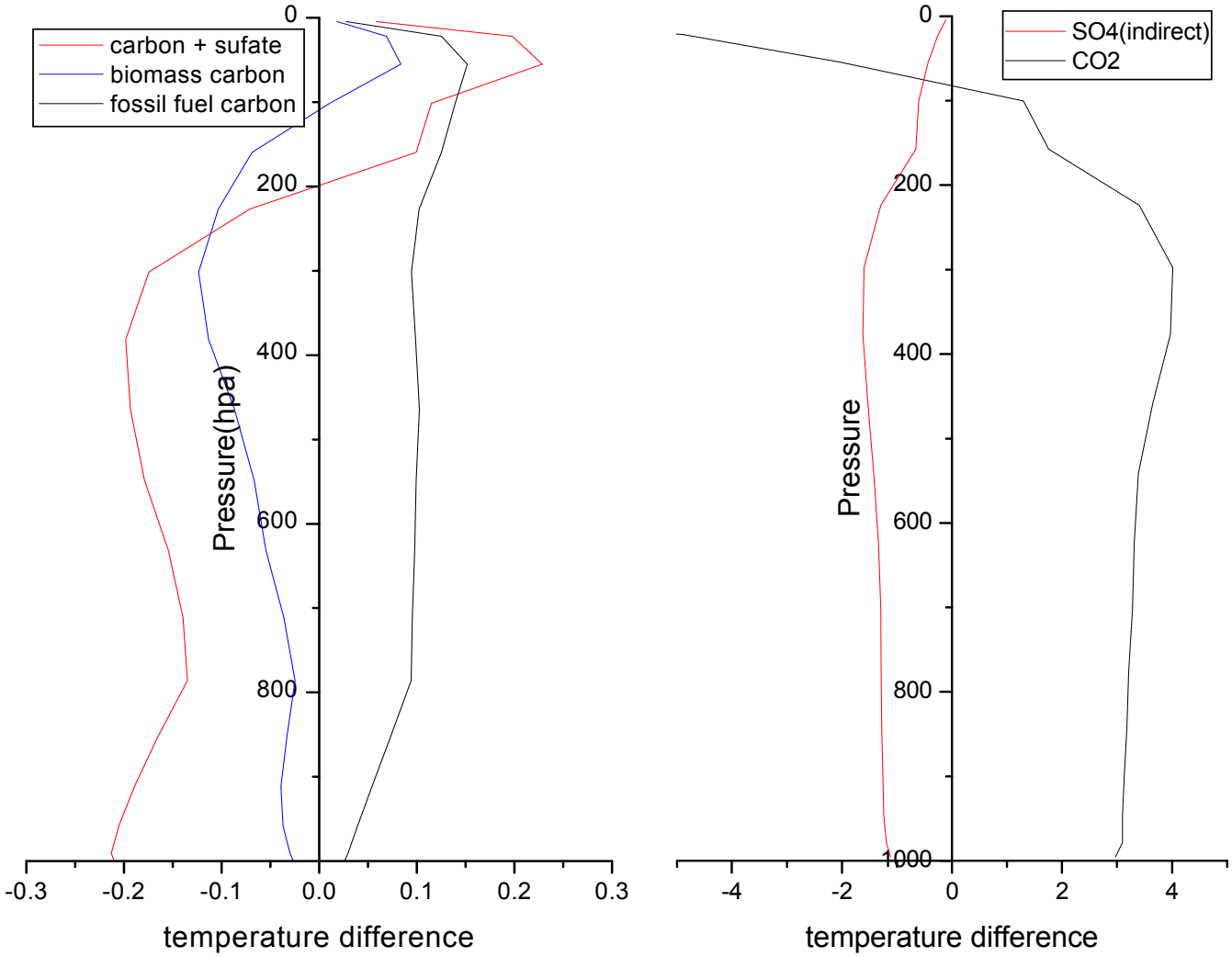
- Greenhouse gases warm the troposphere more than the surface

- Stratosphere ozone cools the troposphere more than the surface.

- Sulfate aerosol gives nearly the same cooling at the surface and in the troposphere.

- Absorbing aerosol (black carbon) warms the troposphere more than the surface.

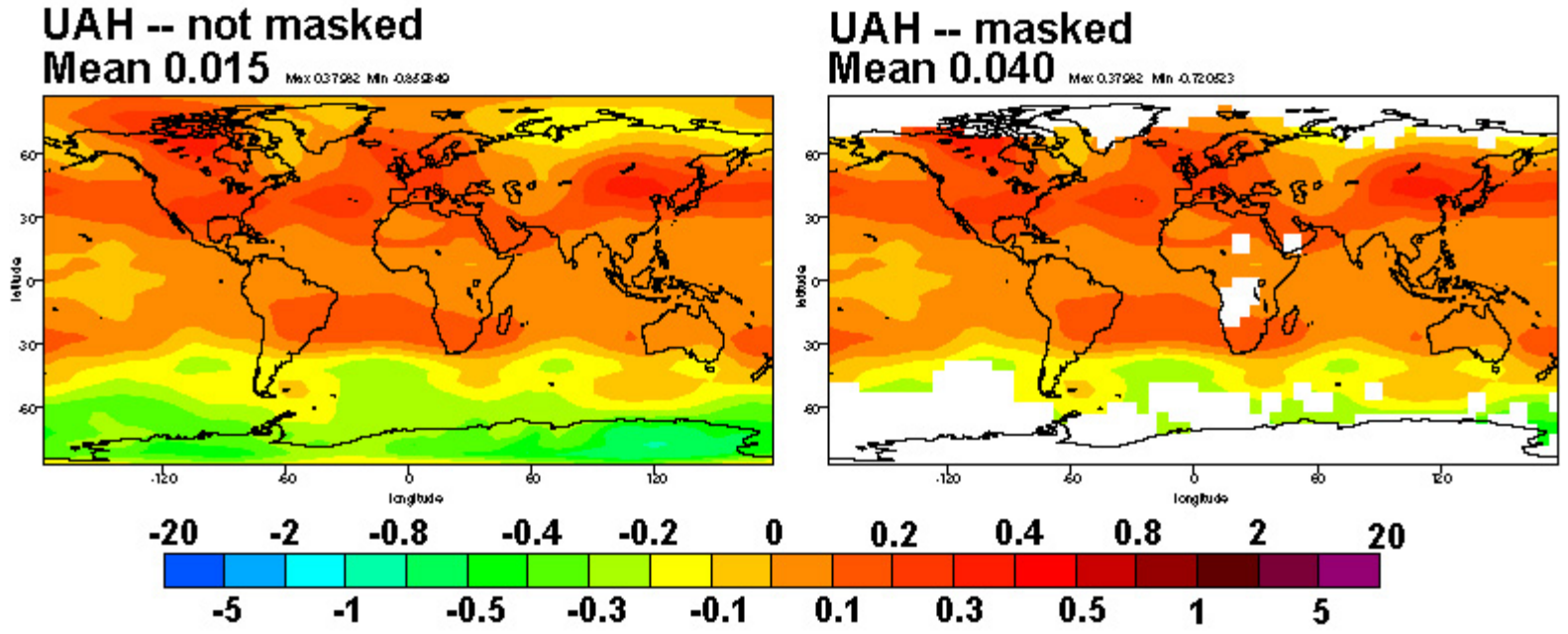
Temperature vertical profile from CO2 and aerosol (CSIRO Q-flux, PD-PI)



- Importance of cooling in the mid-troposphere depends on the relative strength of warming vs cooling

Comparison of MSU trend and surface trend

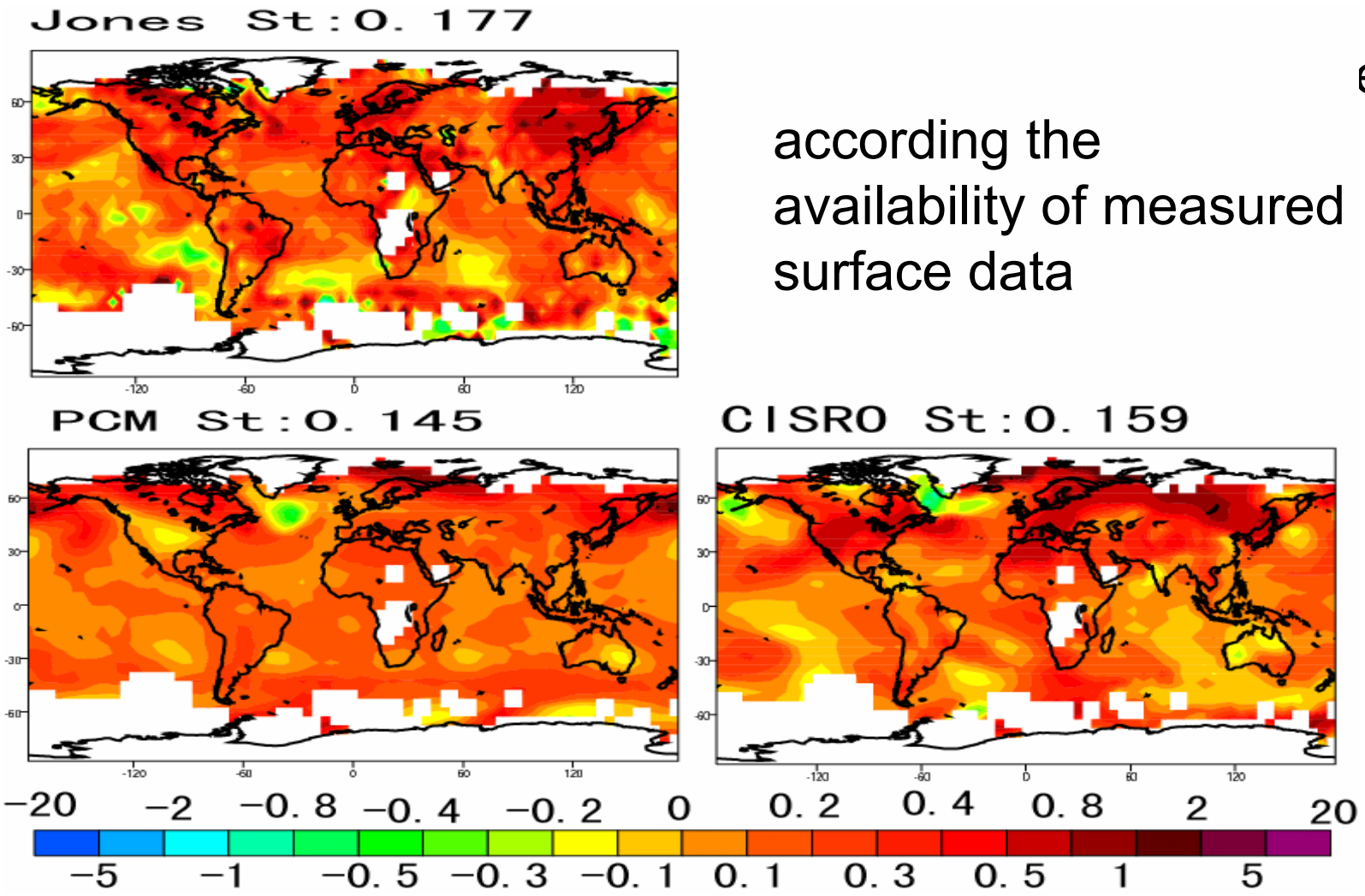
Reported trends have been masked according to availability of surface data



Two transient simulations:

- Transient PCM runs include:
  - Greenhouse
  - Sulfate direct
  - Stratosphere + troposphere O_3
  - Solar
  - Volcanoes
- Transient CSIRO runs include:
  - Greenhouse
  - Sulfate direct + indirect
  - Stratospheric O_3
  - Solar

Spatial pattern for temperature trend at surface (ºK/decade) (1979 - 1999)



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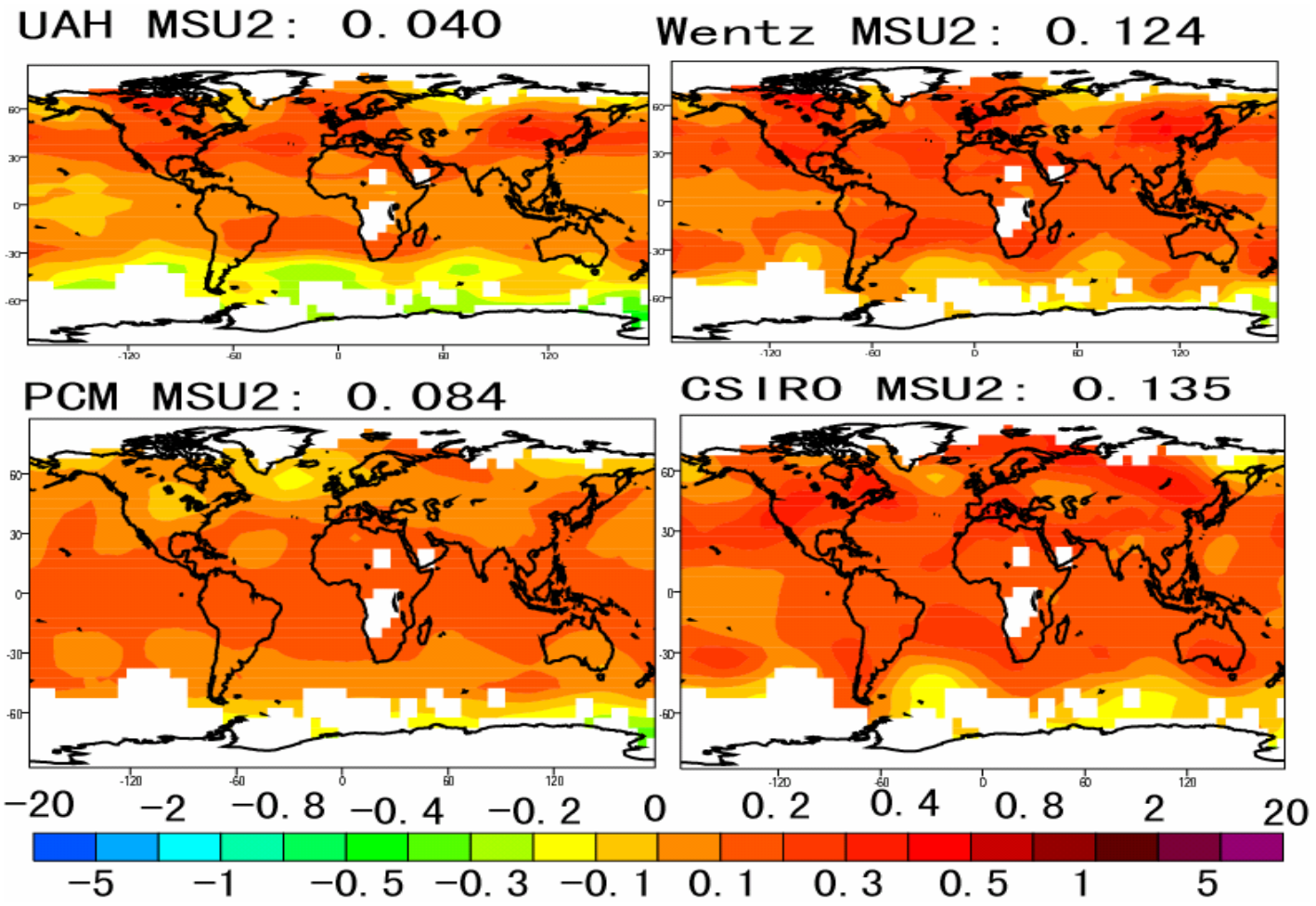
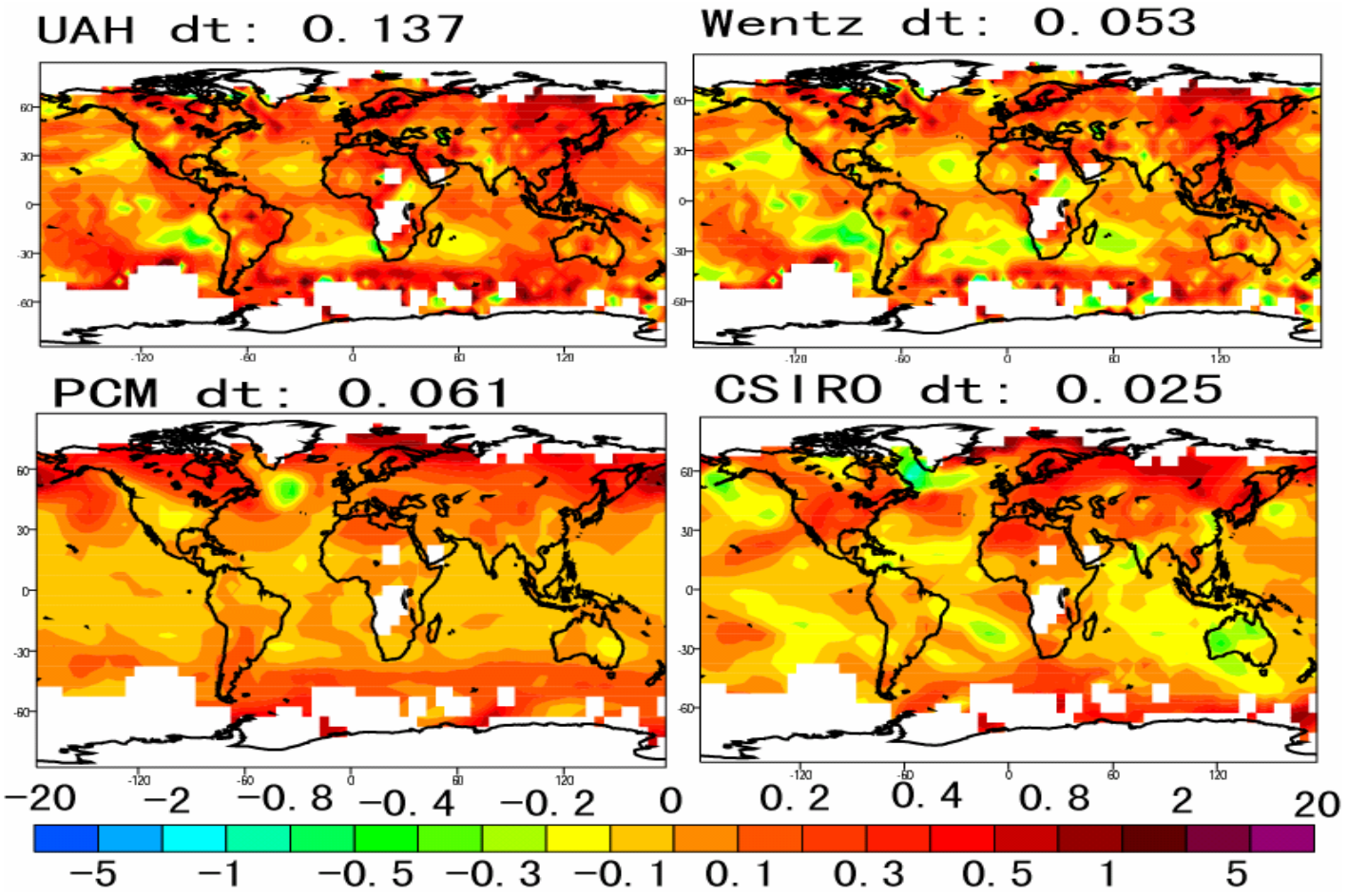
according the availability of measured surface data

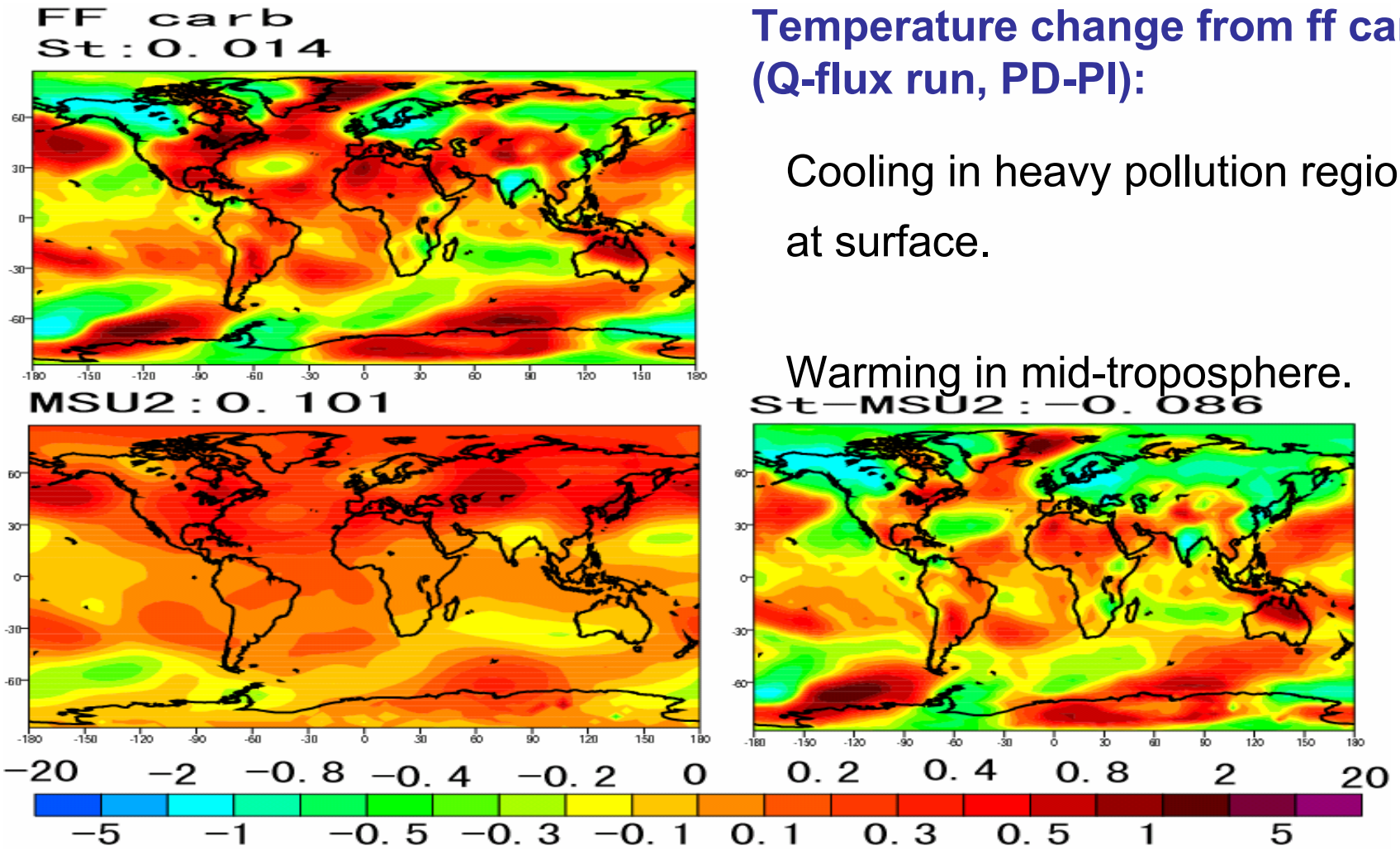
Trend in MSU2(1979-1999)



The trend difference (surface –mid-troposphere)



What is the role of BC in changing these patterns?



Temperature change from ff carb (Q-flux run, PD-PI):

Cooling in heavy pollution region at surface.

Warming in mid-troposphere.

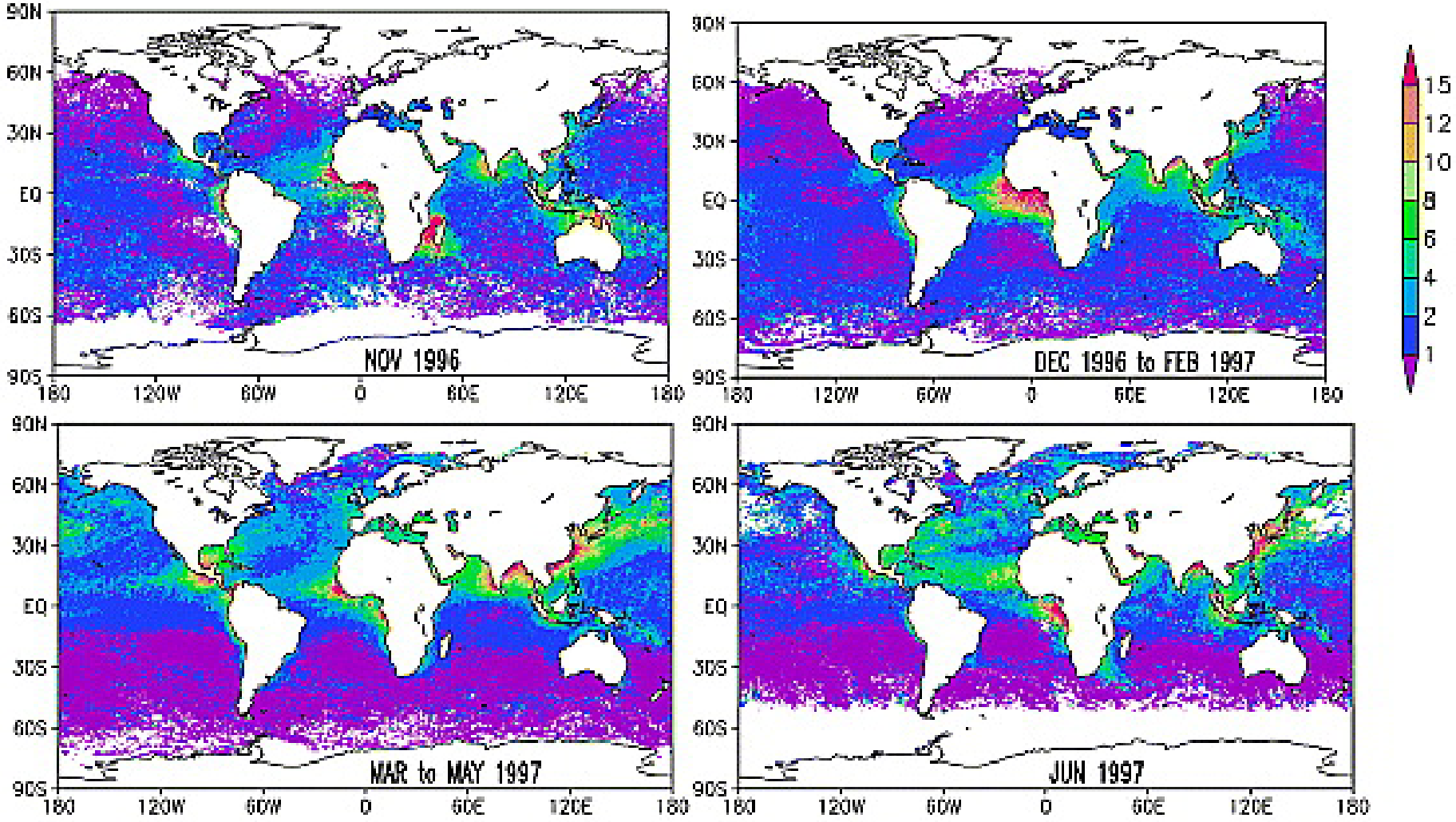
What is the role of BC in changing these patterns?

- The forcing from BC was not included in the PCM and CSIRO transient runs.
- The absorption of atmospheric aerosol may be stronger than the estimate from IPCC 2001 emissions.

Sato et al (2003): the amount of BC in current model should be increased by a factor of 2-4.

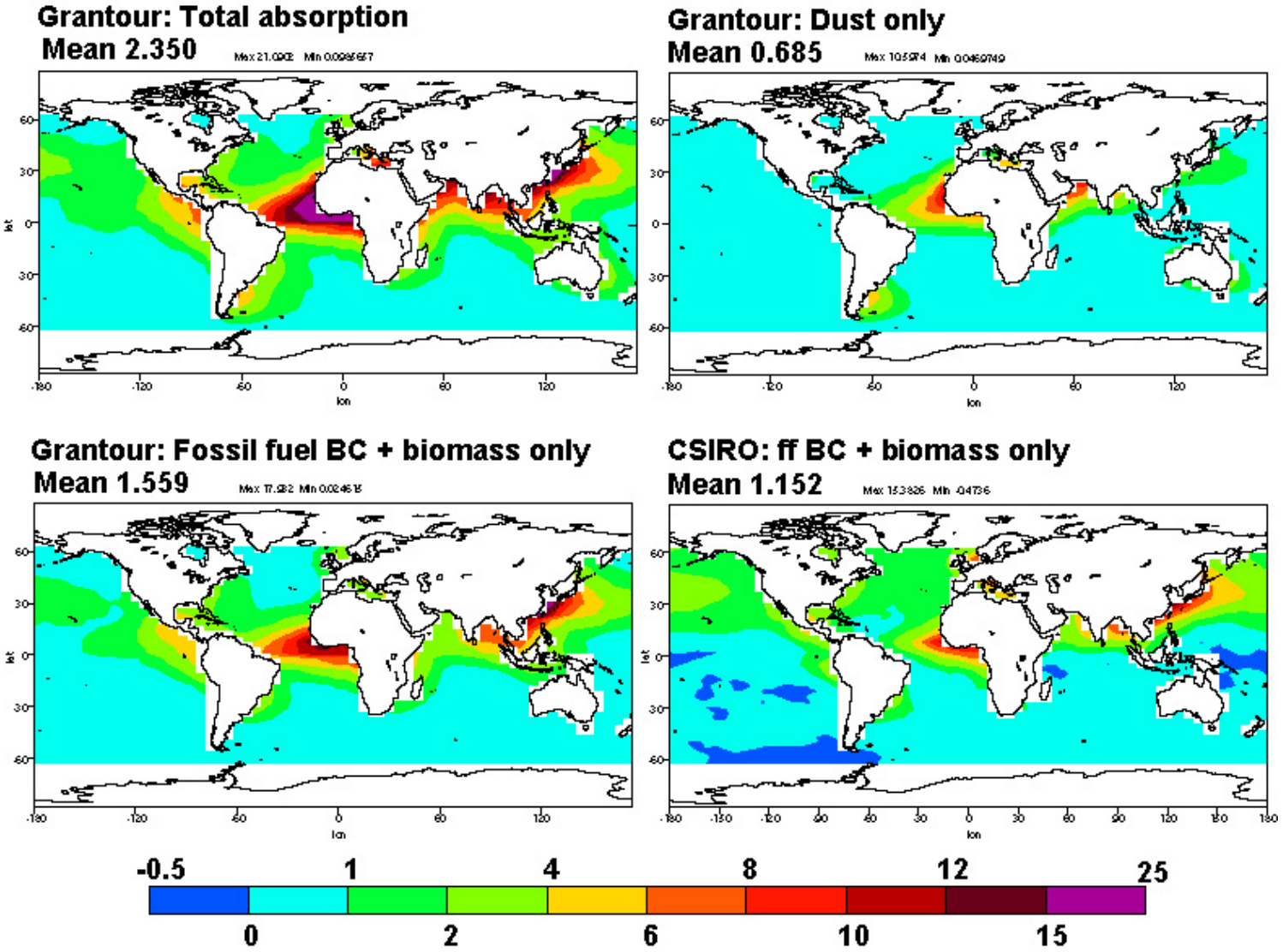
Aerosol absorption over ocean: 3.5-4.5 w/m^2 (Yu et al 2004), 2.5 (2.2-3.1) W/m^2 (Bellouin et al 2003).

Best estimate of aerosol absorption from Polder/ Aeronet = 2.5 Wm^{-2} (Range 2.2 – 3.1)



Bellouin et al., 2003

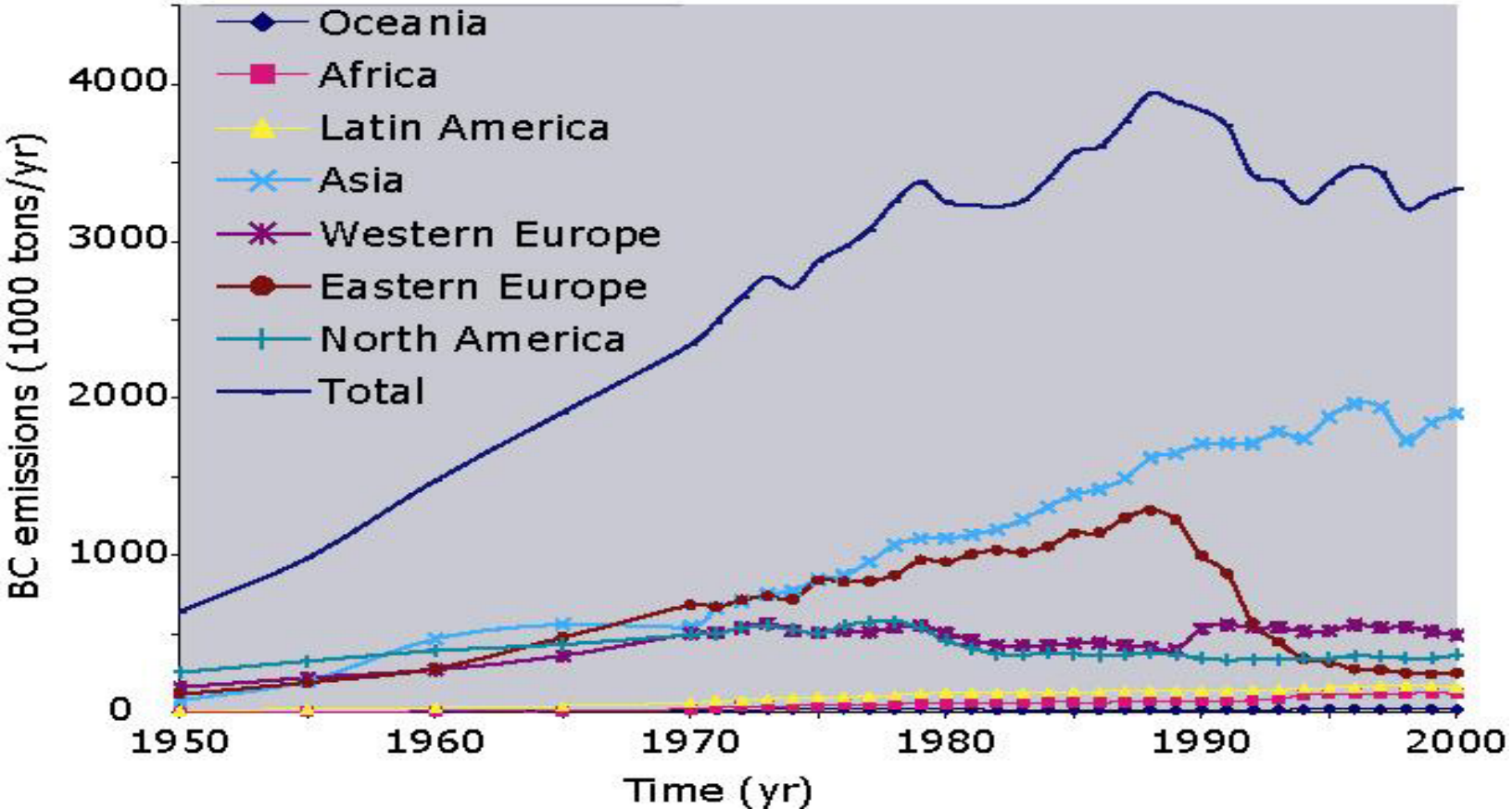
Aerosol absorption in model:
The IPCC emissions model may underestimate BC absorption.



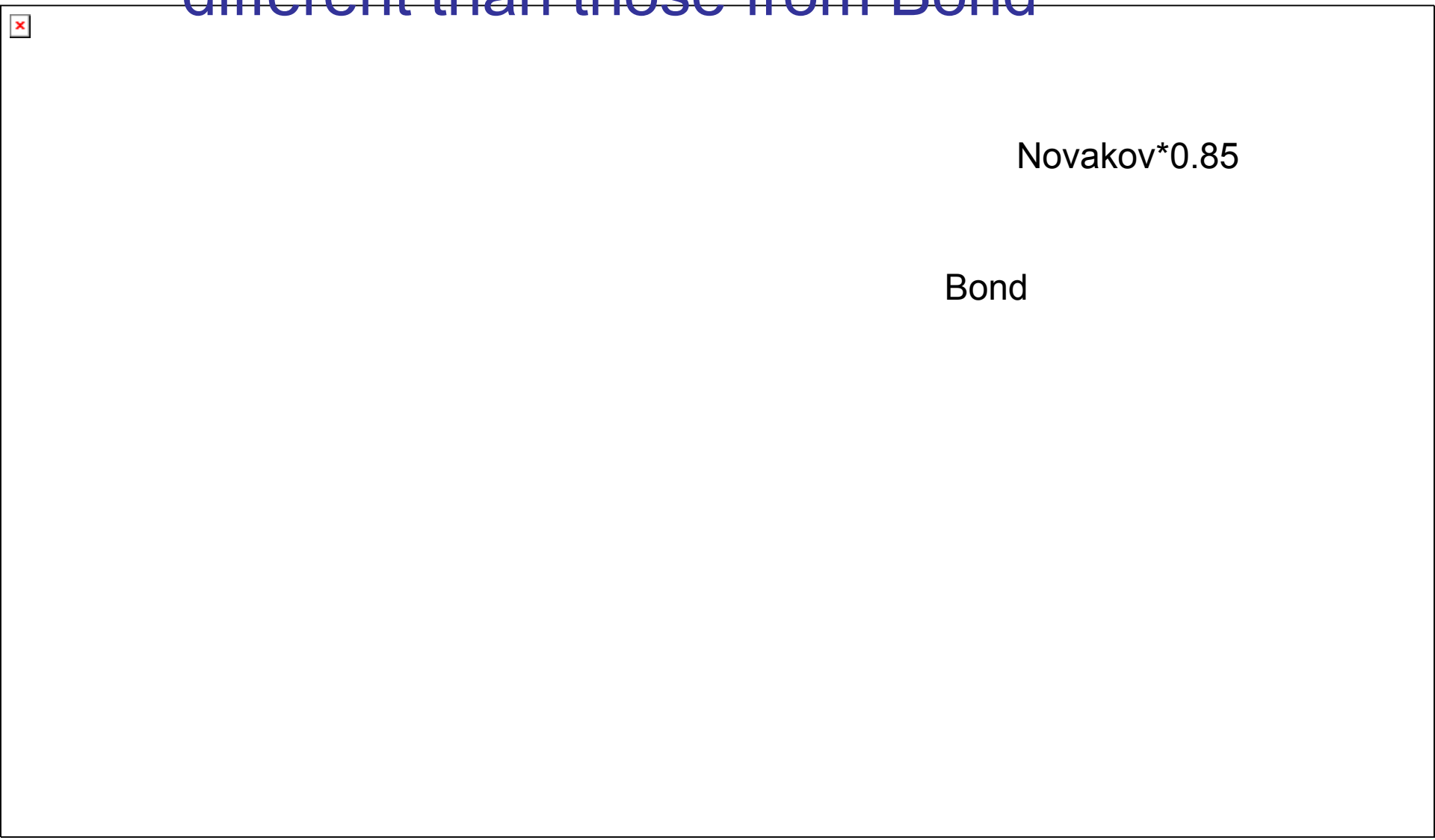
BC emissions from fossil fuel:

Fraction of ff BC+OM temperature change pattern depends on time history of emissions:

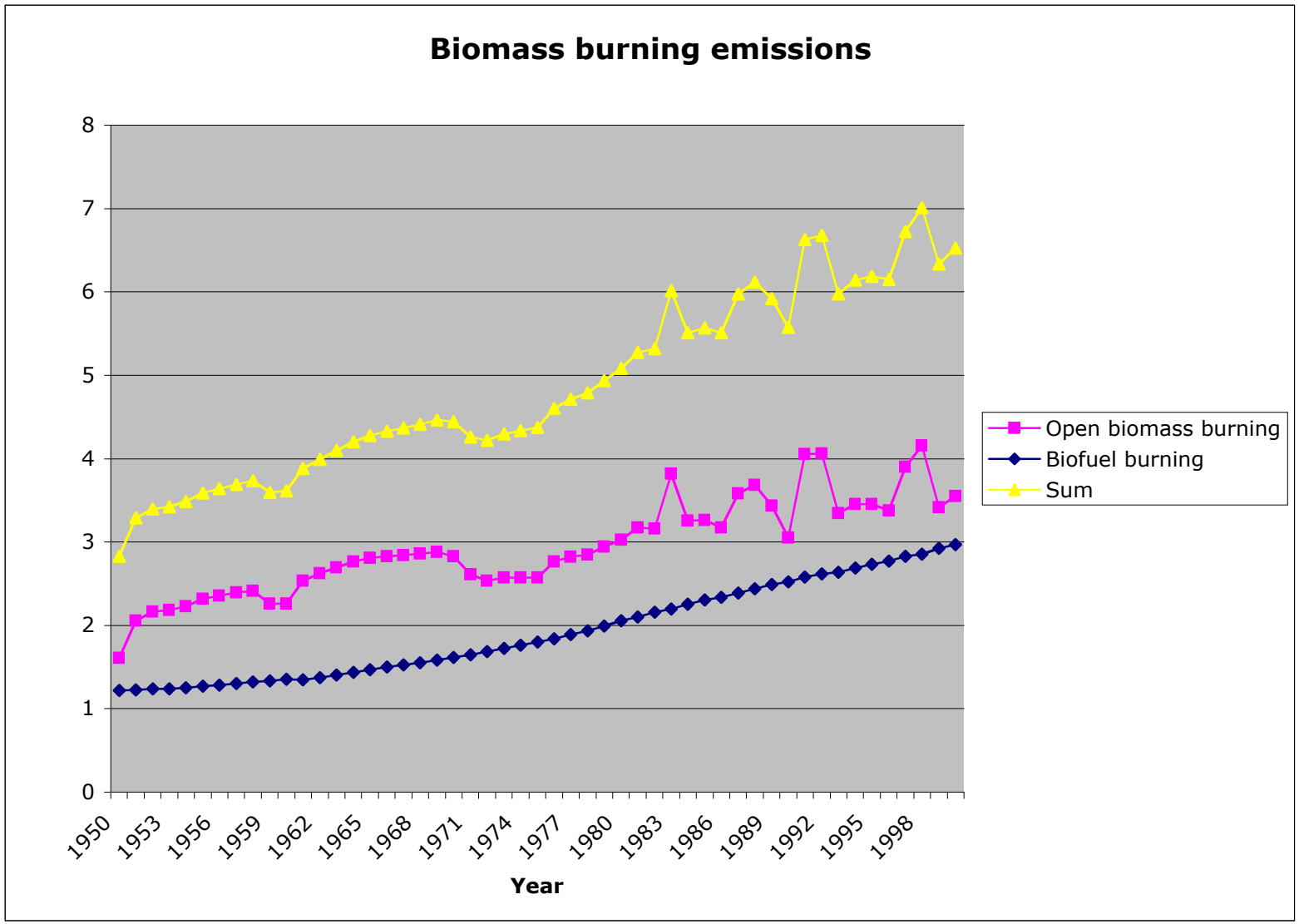
∆Emissions for 1979-1999 are much smaller than those for PD-PI.



Total Emissions and Trends derived using method from Novakov are significantly different than those from Bond



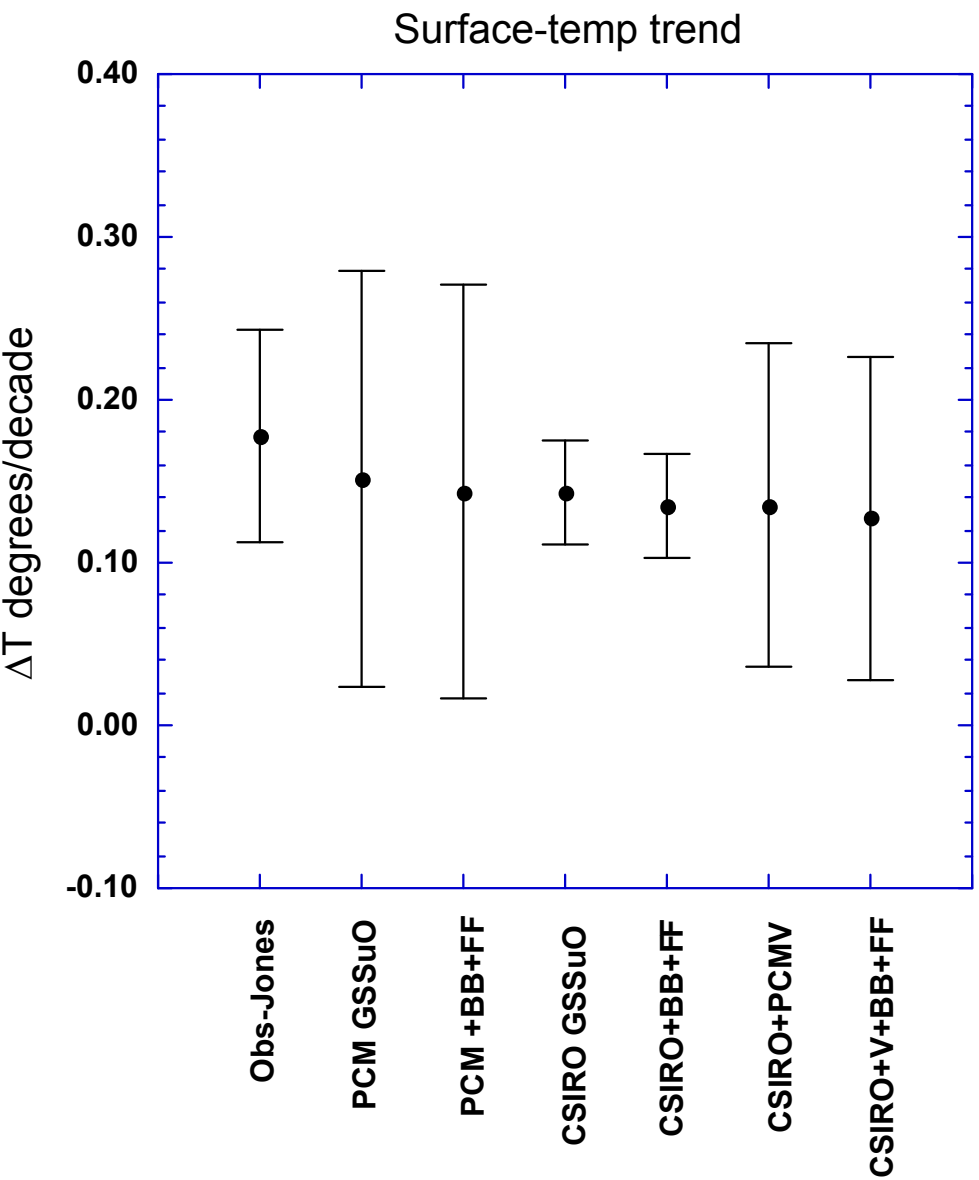
Trends in emissions from biomass burning

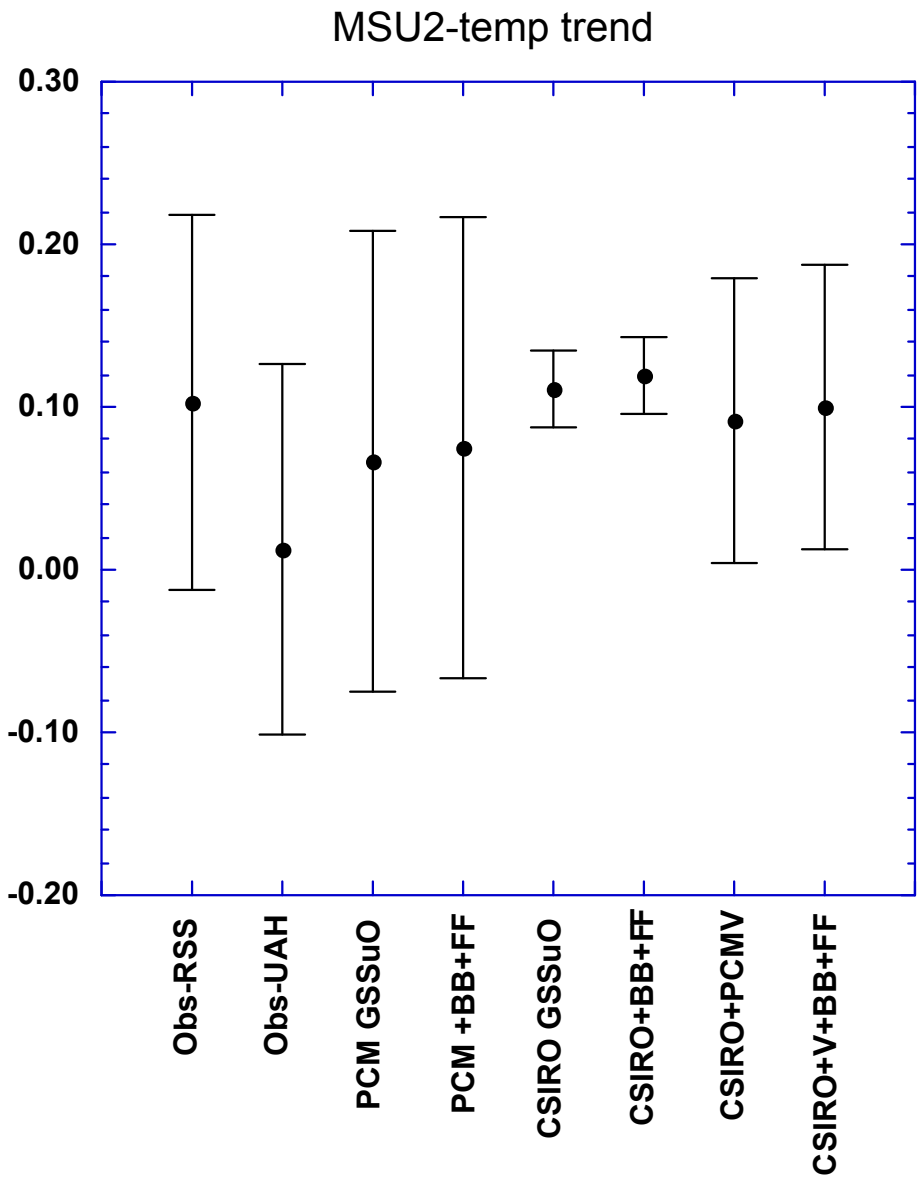


Effect of forcing on pattern of temperature change is approximated

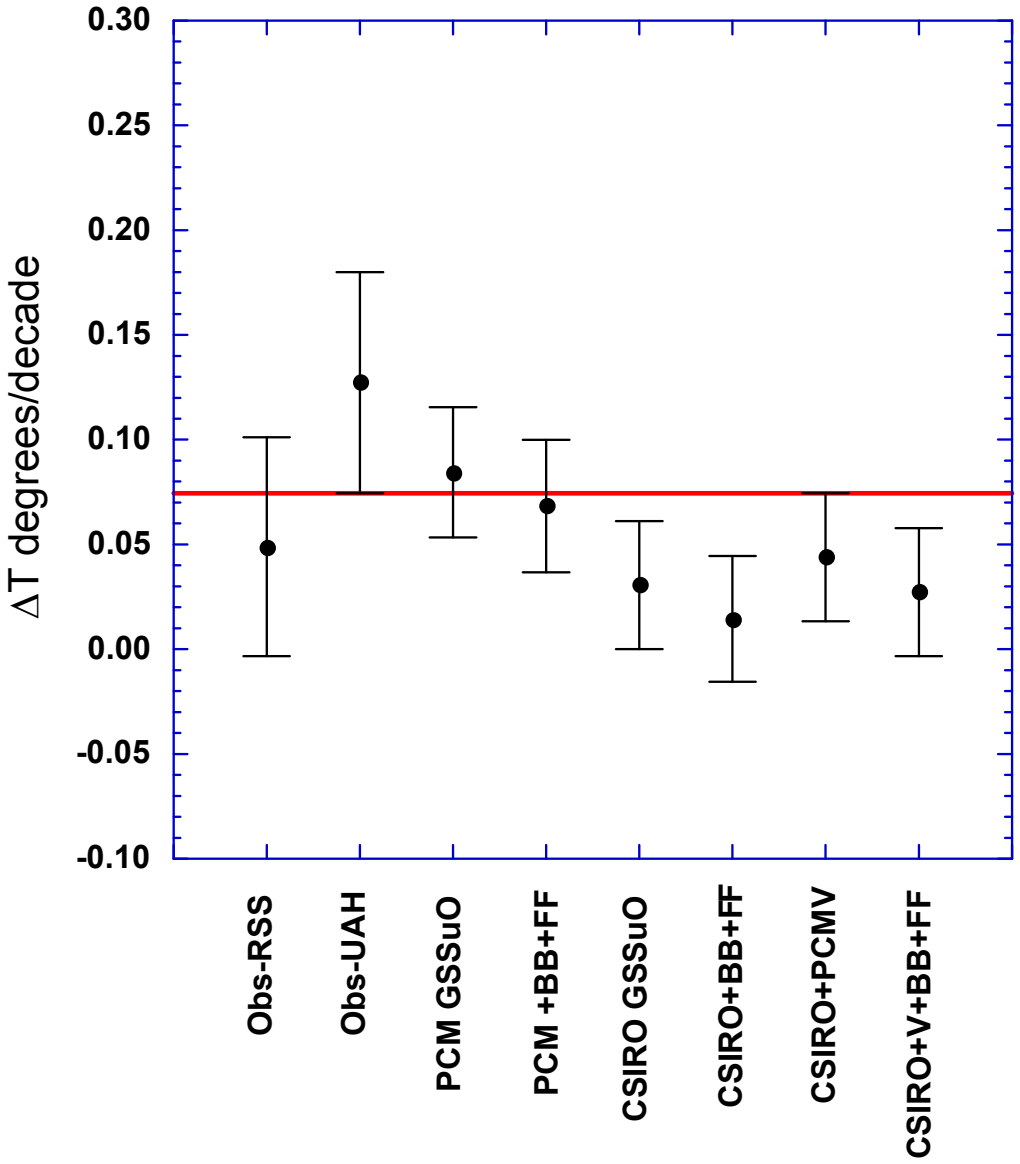
- Add PCM transient model run with volcanic forcing only to CSIRO transient run
- Add fraction of CSIRO fossil fuel BC+OM or fossil fuel + biomass BC+OM pattern to transient trends from PCM and CSIRO models
- E.g.: $DT = E_r(T) / E(\text{q-flux}) \times T(\text{q-flux}) + \Delta T\ (\text{transient})$
  - (assumes global pattern does not change)

Surface and MSU2 trends



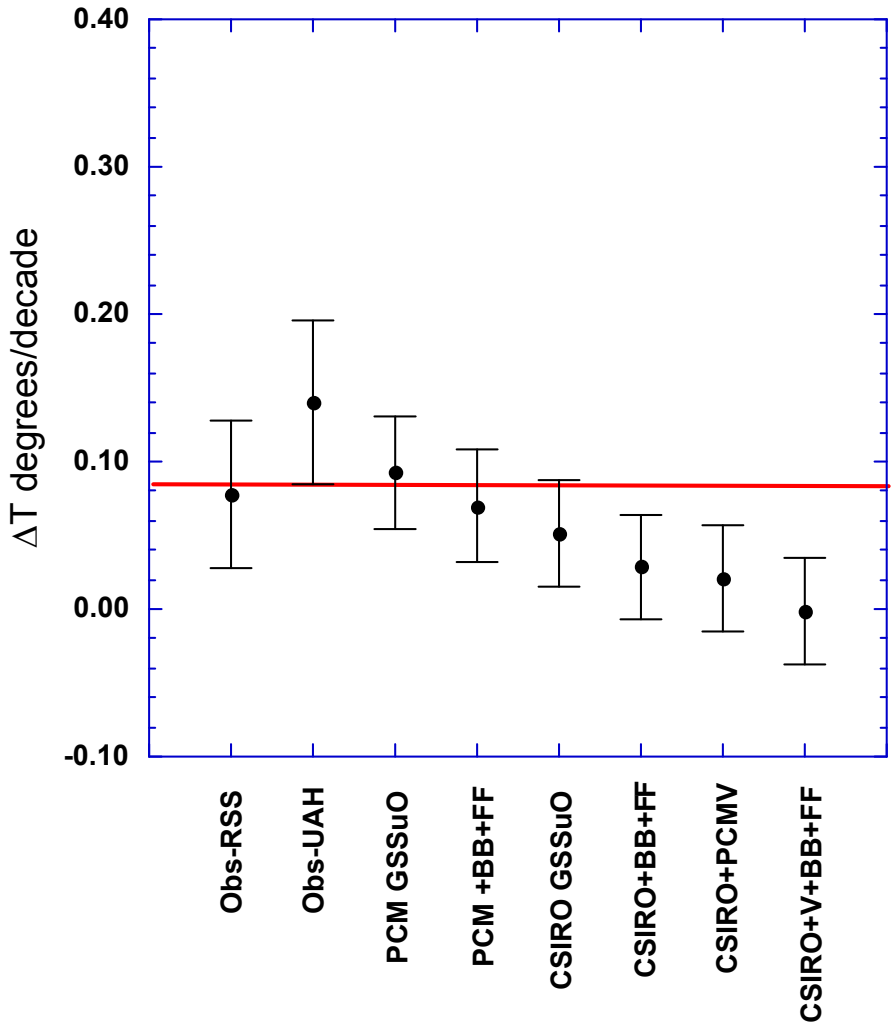


Global Surface - MSU2 trend difference

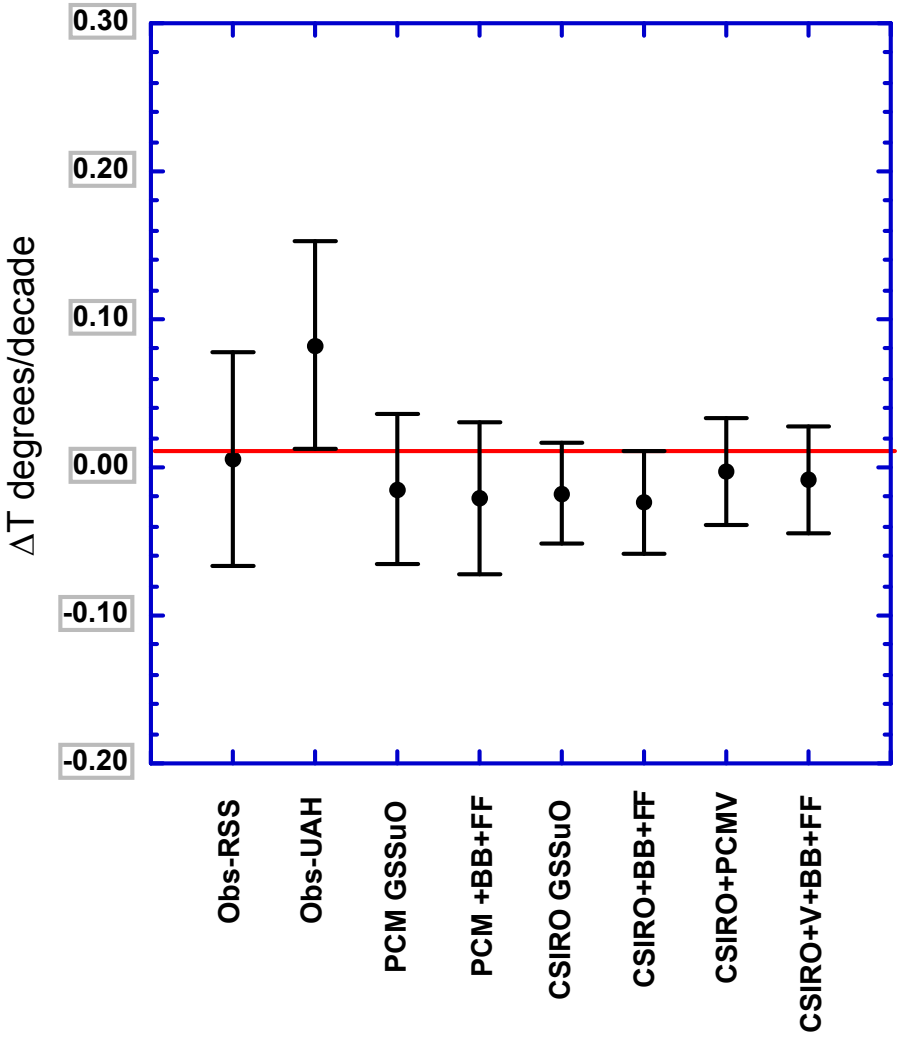


Regional Surface - MSU2 trend difference

Northern Hemisphere



Tropics



Conclusions-issues for future

- Current model results for surface T and MSU2 T are consistent with the magnitude and pattern of temperature change--but might not be if we scale by 2 to account for increased absorption measured in the atmosphere--what is the cause of the extra absorption??

- The 95% confidence intervals for the difference in surface - MSU2 trends for the CSIRO model with FF+BB do not agree with those from Jones - UAH, but the PCM model results even with FF+BB are consistent with both the UAH and RSS data sets -- can we use this comparison to choose between MSU data sets?

- Improvements need to include a transient simulation that includes the time history of regional BC emissions as well as the effect of BC absorption on ice and snow albedos--need good transient inventories

- More than a single model needs to be considered in this type of analysis--Need to understand why models differ